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ABSTRACT

This collection of lesson plans designed for teachers of 4th- through 12th-grade students utilizes an assortment of teaching strategies for topics related to coal and the coal industry. Activities cover the following topics: coal formation; coal identification; "the geologist's dilemma" (a supply and demand activity); geologic time and the formation of coal; history of the coal industry in the United States; coal derivatives; and coal composition. Teaching methods vary with each lesson to include experimentation, simulation, and student interviewing. Experiments allow for the study of coal derivatives through destructive distillation, and for the study of coal composition through moisture and ash analysis. Each experiment lesson plan designates grade level, objectives, discussion techniques, materials, procedures, and results or data collection analysis. One of two simulation lesson plans consists of a coal formation project to observe the conditions present in coal formation. The second simulation lesson plan is a role play activity where students use problem solving skills in resolving any energy source dilemma. A student interviewing activity entails identifying local people who have been involved with coal mining operations in the past. This particular lesson includes sample interview questions and permission slips to be signed by parents and persons interviewed. (MCD)

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COAL ACTIVITIES FOR

SECONDARY

STUDENTS

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COAL FORMATION

OBJECTIVE: The student should be able to simulate and observe the conditions present in coal formation.

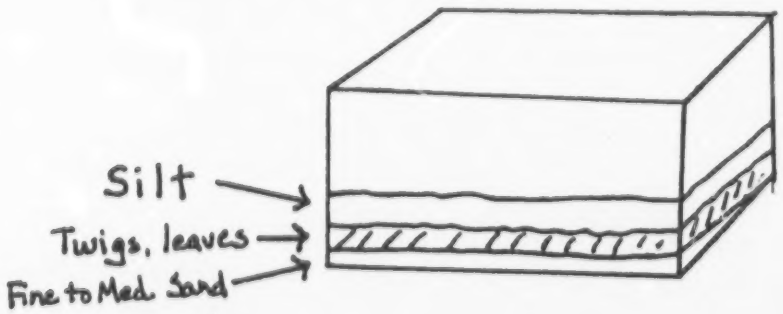
MATERIALS:

Aquarium
Fine to medium grained sand
Fern fronds
Twigs
Plant Leaves
Screen or sifter
Fine silt
Sand

ACTIVITY:

1. Take an aquarium and place about 6 inches of water in it.
2. Spread about 2 inches of fine to medium grain sand on the bottom.
3. Drop in small leaves, sticks and fern fronds. Let it stand for about two weeks. Write down observations of changes in decomposition and color.
4. Wait another two weeks. Then sift fine silt and sand to a depth of 2 inches. Notice the "coal layer".
5. Take out the surface water and let silt and sand dry for a few weeks. There will be plant "fossil" imprints left where the sediments are removed and broken.

TIP: This is a smelly activity. If you have an area where you can put this out of the way and observe occasionally you will like it more!



COAL IDENTIFICATION ACTIVITY

OBJECTIVE: The student should be able to rank, identify and compare the types of coal.

MATERIALS: Coal specimens
Hardness kit (optional)
Bunsen burner or alcohol lamp

PROCEDURE:

1. Carefully examine the coal specimens and complete the identification chart:

Evidence of Plant Origin	Hardness	Luster	Cleavage	Other Characteristics

2. Give evidence that demonstrates peat is the youngest form of coal.

3. Why would anthracite be the highest rank of coal?

4. Using tongs, hold a piece of each type of coal in a flame. Note its speed of ignition, remove from flame and observe how it burns. Complete this chart:

Coal	Speed of Ignition	Flame Color	Speed of Burning	Odor
Peat				
Lignite				
Bituminous				
Anthracite				

5. Does burning show that peat is the lowest ranking of coal?

6. Does the manner of burning of bituminous coal show that it still has volatile (gas) material in it?

THE GEOLOGISTS' DILEMMA

Activity developed by: Indiana Teachers through workshops sponsored by Indiana Council for Economic Education and Public Service of Indiana

GRADE LEVEL: 4-12

OBJECTIVE:

1. Identify when a condition of scarcity exists
2. Determine that resources are limited, and thus scarce
3. List some of our chief energy sources

MATERIALS:

A glass jar
Beads - four differenct colors
Cornmeal - same quantity as beads

About 50 percent of the beads should be black, 3 percent red, 10 percent white and 37 percent blue. Since the beads represent our energy sources, which are unknown to all, do not attempt to count all the beads. Note: Any resources not found the first time are waiting to be recovered the next time the game is played.

PROCEDURE:

1. Throw the beads and cornmeal high into the air, letting them scatter over the room. Divide the class into five companies. Each of the companies will search for one of our energy resources represented by one color bead.

   Company #1: black bead (coal)
   Company #2: red bead (uranium)
   Company #3: white bead (natural gas)
   Company #4: blue bead (oil)
   Company #5: cornmeal (solar)

   NOTE: Do not interfere or comment if any company starts to collect all colors.

2. Allow the companies to search for one minute. Have each company count its resources. Keep the resources in separate piles. Record the totals for each group for each round on the chalkboard.

3. Start a second search for one minute. Each company must search for resources still missing. Record totals.

4. Do the same for a third one-minute round.

5. Discuss the following questions:

   a. Which energy sources were easier to collect? Why? Which were the most difficult? Why?

   b. What makes them easy or difficult to find? Is is the availability of the beads or is it the skill of the searchers?

   c. Looking at the piles of energy from each of the different rounds, which is greater? Why? Which round is the smallest? Why?

   d. Did anyone collect more than one energy resource? Is it realistic to collect more than one?

   e. As energy resources become more scarce and demand continues to increase, what should happen to the price or cost of energy resources?

GEOLOGIC TIME
WHEN WAS COAL FORMED?

Activity developed by:

Beverly Bowers
Mannington Middle School
Fairmont, West Virginia

GRADE LEVEL:

Eighth Grade or Higher

OBJECTIVE:

The student shall construct a time line of geologic periods and label the major happenings in each. The student should pay attention to the climate and conditions during the coal forming periods.

MATERIALS:

Adding machine tape 5 meters long
Metric ruler
Tape

INFORMATION AND BACKGROUND:

The students should have a general knowledge of epochs, periods and eras. They should make a chart similar to the one provided. Research can be done ahead of time by dividing the class into groups and give each group a period to research. This information can be added to the chart. Students should work in groups of two to construct the time lines. Be sure to have a large area (a long hallway is good) in which to work.

PROCEDURE:

1. Measure and cut off a strip of adding tape that is 5 meters long. One meter = one billion, one centimeter = ten million, and one millimeter = one million

2. Tape adding machine tape to a flat surface where you can work easily.

3. Draw a line near the end of the tape. This will be the beginning of the earth. Measure 4 meters from this mark and draw a line. Label it "End of Precambrian Time." Starting at this line, mark the distance that will represent the end of the Paleozoic Era. Label it "End of Paleozoic Era." Go back and divide the part of the tape representing the Paleozoic into correct lengths representing each period of this era. Label each with the correct name. Do the same with each era and period. Go back and label the main events in each era.

Era	Period	Length in years	Length on tape	Major Events
Precambrian				
Total Length		4 bill.		
Paleozoic	Cambriam	70 mill.		
	Ordovician	70 mill.		
	Silurian	35 mill.		
	Devonian	50 mill.		
	Mississippian	25 mill.		
	Pennsylvanian	40 mill.		
	Permian	55 mill.		
Total Length		354 mill.		
Mesozoic	Triassic	35 mill.		
	Jurassic	54 mill.		
	Cretaceous	71 mill.		
Total Length		160 mill.		
Cenozoic	Tertiary	63 mill.		
	Quarternary	=======		

LIVING HISTORY UNIT

GRADE LEVEL: Middle or High School

OBJECTIVE:

1) Organize thoughts into coherent questions
2) Improve verbal skills
3) Write a report using notes

MATERIALS:

Permission slip
Paper
Pencil

PROCECURE:

1. Student will identify person who was or is directly or indirectly involved in the coal industry. This may a person who is or did work at a coal mine. It may be someone (grandparent) who used coal to heat the house. It may be someone who works for an electric company that uses coal.

2. Contact person to see if you may conduct an interview.

3. Fill out permission slip and return to teacher.

4. Develop a list of questions to ask the interviewee.

5. Conduct the interview at the scheduled time.

6. From the interview notes, write a report on what the interviewee said.

NOTE: A tape recorder may be used and the interviews put on one tape for a class record.

SAMPLE QUESTIONS: Coal Mine History Interview

What country were you born in?
Where did you first live in this area?
How old were you when you started in the mine?
What was the name of the mine and where was it?
Who owned the house you lived in?
Where did you shop?
What were your wages?
Describe your home.
What jobs did you have in the mine?
What was the ethnic breakdown of your community?
What was the greatest change you saw in coal mining?
Did unions develop slowly or rapidly in your area?

SAMPLE PERMISSION SLIP

Student Name: _____

Person Accompanying Student on Interview: _____

Date and Time of Scheduled Interview: _____

Place of Interview: _____

_____

Parent's/Guardian Signature and Phone Number approving of above arrangements

(This portion to be returned to teacher)

Person to be Interviewed: _____

Student Interviewer: _____

I have agreed to this interview and I allow all or part of it to be recorded, replayed or transcribed as long as it is not for profit.

_____

Signature of interviewed person

COAL DERIVATIVES BY DESTRUCTIVE DISTILLATION

Activity developed by:

Linda N. Dressler
Mt. Vernon Junior High
Mt. Vernon, Indiana

GRADE LEVEL:

Eighth Grade or Higher

OBJECTIVE:

This is a "hands-on" activity demonstrating the production of coke, one of the most widely used raw materials derived from coal. This activity may also serve to stimulate student research into the differences in coal types and coal products.

DISCUSSION:

Coal is a fossil fuel formed by the anaerobic (without the presence of oxygen) decay of plants that lived millions of years ago. The energy found in coal is solar energy stored by the plants. It remains in the hydrocarbons left behind during the decay process. We can burn these hydrocarbons and release the stored energy.

During the formation of coal, it goes through several stages which differ in the amount of moisture and nitrogen impurities remaining in the organic material. The first three stages of coal are sedimentary rock formed by layers of silt covering the decaying plants. The moisture and nitrogen impurities are squeezed out of the material by the weight of the silt deposits. Peat and lignite are early stages that are found on or near the surface of the earth. Although these materials will burn, the flame is smoky because of the moisture content. Bituminous, or soft coal, is the third stage and the most abundant type of coal. It has lost most of its moisture and nitrogen impurities and is an efficient heating material. The final stage of coal, anthracite, is a metamorphic rock. It is found only in areas where tremendous pressure and heat from mountain building processes can change the bituminous coal into a hard substance which is mostly carbon. Anthracite is the cleanest of all coal, since it has the least impurities.

Although coal accounts for 20 percent of total US energy use and is the major source of fuel used in the

production of electricity, its derivatives serve as raw materials in manufacturing. Many coal derivatives are produced indirectly by the destructive distillation of bituminous coal. This process takes place in the absence of oxygen (within an airtight oven) and prevents the coal from burning. The remaining material, coke, is nearly pure carbon. It is the most widely used coal derivative and is burned by mills to change ore into pure iron that is needed to make steel. Some of the gases produced during the distillation process can be refined to form ammonia, coal tar and light oil. Manufacturers can use these products to make a variety of products.

This lab activity will use bituminous coal to produce three derivative mixtures during a destructive distillation process.

MATERIALS:

Soft coal sample
Flame source
Crushed ice
Ring stand
Pyrex or Kimax test tube
Gas bottle or flask
2-hole stopper
Test tube holder
Bent glass tubing
Large beaker
Wooden splints

PROCEDURE:

1. Place some small lumps of bituminous coal in a Pyrex or Kimas test tube and clamp the test tube to a ring stand.

2. Use a bent glass tube to attach the test tube to a gas bottle. Be sure the glass tube does **NOT** touch the bottom of the bottle. (See diagram).

3. Insert a bent tube into the two-hole stopper in the gas bottle. The other end of the tube should be drawn to a narrow opening at one end.

4. Place the bottle in a beaker of crushed ice.

5. Heat the coal slowly by moving a flame back and forth along the test tube.

6. After several minutes, bring a lighted wooden splint to the tip of the narrow tube. Does the coal gas produced burn?

7. When no more gas is produced, turn off the flame. Remove the beaker from the ice.

8. The bituminous coal in the test tube has been changed to coke.

9. The liquid in the bottom of the beaker is coal tar.

RESULTS:

Below are sample questions for your students to answer.

1. Record your observations as you placed a lighted splint to the narrow tube opening in step 6 in in the procedure.

2. Describe the mixture that remains in the test tube at the conclusion of the experiment.

3. Describe the mixture that forms in the gas bottle that was submerged in crushed ice.

EVALUATION AND INVESTIGATIONS:

Answers to some of these questions can be found in the discussion section of this activity and other questions involve outside research.

1. Define the following terms used during the discussion:

   Anaerobic
   Coke
   Hydrocarbons
   Organic

2. Describe the characteristics of the following stages of coal (include common name, physical characteristics, chemical composition, burning attributes)

   Anthracite
   Bituminous
   Lignite
   Peat

3. a) How is the decay process that forms coal similar to the distillation process from which coal is derived?

   b) How is combustion (burning) different than destructive distillation?

   c) Why is the difference important?

4. a) What coal is used to produce coke?

   b) What regions of the U.S. mine this type of coal?

   c) What restrictions are placed on the type of coal used for carbonization (coke-making)?

   d) How does this effect the coal mined in this area?

5. a) Ammonia (NH_4) is derived from the gases produced during the destructive distillation. What substance in coai produced this compound?

   b) Could ammonia be derived from anthracite distillation?

6. What are some possible uses for coal tar and coal gas?

DETERMINING THE MOISTURE AND ASH CONTENT OF A COAL SAMPLE

Activity developed by:

Dot Helms
Mt. Rowan High School
Mt. Ulla, North Carolina

This activity was developed during a summer program sponsored by the National Science Teachers Association, National Science Foundation and Duke Power Company.

GRADE LEVEL: High School

DISCUSSION: Coal is delivered to Duke Power Laboratories in pieces about the size of small rocks. The preparation of a coal sample for laboratory analysis involves two procedures -- air drying and reduction division. The following procedures will enable you to simulate these important tests necessary for the effective utilization of coal. The coal used at Duke Power comes from West Virginia and Kentucky.

MATERIALS:

Coal sample
Drying oven
Thermometer
Crucible
Balance (sensitive to 0.0001 g)
Mortar and pestle
Tongs
Sieves (screen of different sizes)

PROCEDURE #1
AIR DRYING:

1. The coal sample is air dried to bring the content into equilibrium with the ambient moisture. The massed sample is heated 10-15 degrees above the ambient temperature for eight hours. Allow to cool to room temperature.

2. The dried sample is massed and moisture content recorded. **Hint:** Handle the crucible with tongs at all times for more accurate data.

PROCEDURE #2
REDUCTION DIVISION:

1. The dried sample is pulverized using mortar and pestle until it is the consistency of a fine powder.

2. The sample may be divided at any time during the pulverization in order to obtain the finest small samples.

3. Continue the grinding until the entire sample is pulverized.

4. Divide the sample into 10-gram lots for future laboratory exercise.

5. Seal the samples into small plastic bags. Be sure to label as pulverized coal samples for moisture and ash analyses.

6. Be sure and clean your equipment and lab area.

DATA COLLECTION/ ANALYSIS:

1. Use the table below to determine the air drying loss:

Sample Number	Initial Mass	After Drying	% Air Dried (ADL) Loss
	Crucible	Crucible	
	Crucible + Coal	Crucible + Coal	
	Crucible	Crucible	

2. Calculate the air dried moisture loss in the analysis sample as follows:

$$\% \text{ air drying Loss} = \frac{\text{Initial sample mass (g)} - \text{Dried sample mass (g)}}{\text{initial sample mass}} \times 100$$

3. Make a table for your lab report to include three samples of coal.

COAL MOISTURE ANALYSIS

BACKGROUND:

This exercise is in conjunction with the drying loss of of a coal sample. Analytical results can be obtained by establishing the loss in mass of a sample when heated under controlled conditions of temperature.

MATERIALS:

Crucible
Spatula
Tongs
Balance (sensitive to 0.0001 g)
Desiccator
Prepared coal sample

PROCEDURE #1
HEATING THE SAMPLE:

1. Heat the empty crucible and cover in oven maintained at a temperature of 104-110 deg. C. After one hour, remove the crucible from the oven and cool in a desiccator for 15-20 minutes.
2. Using tongs, record the empty crucible weight.
3. Using a spatula, transfer approximately 1 g of the coal sample to the crucible and mass to the nearest 0.0001 g and record grams as W1. Subtract the crucible from the sample mass (W1) and record mass as W3.
4. Secure the crucible in a desiccator and transfer into a pre-heated oven at 104-110 deg. C.
5. Heat for one hour without the lid on the crucible.
6. Place the cover on the crucible and transfer into the desiccator for 15-20 minutes to cool. Re-mass the crucible to the nearest 0.0001 g and record the weight in grams as W2.

PROCEDURE #2
CALCULATION OF THE MOISTURE CONTENT:

1. Calculate the percent of moisture in the analysis sample as follows:

$$\% \text{ moisture, uncorrected} = \frac{W1 - W2}{W3} \times 100$$

Where W1 = mass of crucible and sample in grams
W2 = mass of crucible
W3 = mass of sample in grams

2. Calculate the total percent moisture as follows:

$$\text{\% moisture (AR) previous lab} = \frac{M \times 100 - ADL}{100 + ADL}$$

AR = "As received" from
M = % moisture from procedure #2, step #2

Sample	% Moisture
	Uncorrected
	ADL
	Uncorrected
	ADL

3. Make a table for your lab report to include two samples of coal.

COAL ASH ANALYSIS

BACKGROUND:

This procedure is in conjunction with one of the samples obtained in the previous exercise. Ash content, one of the important environmental concerns, can be determined by massing the residue remaining after burning a sample of coal under controlled conditions. Duplicate results may be necessary for increased accuracy. Difficulty may be experienced in securing satisfactory determinations of ash for coal unusually high in calcite and pyrite. Gradual initial heating is necessary to avoid mechanical loss from a too rapid explusion of the volatile matter. **Caution:** It is necessary to use the ventilation hood.

MATERIALS:

Crucibles
Fischer burner
Tongs
Desiccator
Balance (sensitive to 0.0001 g)
Ventilation hood
Prepared coal samples

PROCEDURE #1

1. Clean crucible and dry one hour or longer in drying oven. Cool 15-20 minutes in a desiccator.
2. Mass the crucible and record in grams as W1.
3. Transfer 1 g of the sample to the massed crucible. Re-mass and record the sample mass as W2 (crucible mass - re-mass). **Hint:** In no case should the mass of a coal sample be less than 1 g.
4. Turn on the ventilation hood. Place the covered crucible in the ventilation hood over a burner. Heat constantly at least 25-30 minutes.
5. Turn off the burner and ventilation hood. As soon as the crucible returns to normal color (5-10 minutes), use the tongs and transfer the sample to desiccator.
6. After cooling for 30-35 minutes in the desiccator, mass the sample to the nearest 0.0001 g. Record this mass in grams as W3.

7. Open the crucible and examine for complete combustion.

8. If coal is still visible, return to Step 4 and repeat.

DATA COLLECTION/ ANALYSIS:

1. Tables 1-3

Table 1
Laboratory

Temperature	Humidity

Table 2
Heating/
Drying

Time Burner Desiccator	Trial 1	Trial 2

Table 3

Sample #	Mass Crucible	Sample Before Δ	 After Δ

2. Calculate the percent ash in the sample as follows:

$$\% \text{ Ash (uncorrected)} = \frac{W3 - W1}{W2} \times 100$$

Where W1 = mass of crucible
W2 = mass of sample in grams
W3 = mass of ash and crucible in grams

3. Calculate the percent ash to "moisture free" (MF) as follows:

$$\% \text{ Ash (MF)} = \% \text{ Ash (AR)} \times \frac{100}{100 - \% \text{ AR moisture}}$$

4. Duplicate the sample tables for your report.